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N.C. 72939

CLOSED BRAYTON CYCLE DIRECT CONTACT REACTOR/STORAGE TANK WITH O_2 AFTERBURNER

TO ALL WHOM IT MAY CONCERN

BE IT KNOWN THAT PAUL M. DUNN employee of the United States Government, citizen of the United States of America, and resident of Wakefield, County of Washington, State of Rhode Island, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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CLOSED BRAYTON CYCLE DIRECT CONTACT REACTOR/STORAGE TANK WITH O_2 AFTERBURNER

This patent application is copending with the related applications by the same inventor filed on the same date as subject patent entitled Closed Cycle Brayton Propulsion System with Direct Heat Transfer, ~~identified as Navy Case No. 71843~~ a1, Closed Brayton Cycle Direct Contact Reactor/Storage Tank with Chemical Scrubber, ~~identified as Navy Case No. 72910, Closed~~ a2 Cycle ~~Brayton~~ Power System with Direct Heat Transfer, ~~identified as Navy Case No. 73348~~ a3, and Semiclosed Brayton Cycle Power System with Direct Combustion Heat Transfer, ~~identified as Navy Case No. 73825~~ a4.

Ins. a1 Ins. a2 Ins. a3 Ins. a4

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to metal vapor control of the liquid metal fuel used in a direct contact Brayton cycle power system. More particularly the invention relates to a system for

eliminating metal vapor at the working gas outlet of a closed Brayton cycle direct contact reactor/storage tank by use of an O_2 afterburner.

(2) Description of the Prior Art

My invention titled Closed Cycle Brayton Propulsion System with Direct Heat Transfer, with which this application is copending, discloses the use of the more efficient Brayton cycle instead the Rankine cycle in a closed cycle underwater propulsion system. The size and weight penalty of the Brayton cycle's hot side heat exchanger is eliminated by use of direct contact heat transfer between the working fluid which is an inert gas such as helium, argon, xenon, or a mixture of inert gases, and a liquid metal bath of a material such as lithium, sodium, potassium, aluminum, magnesium, or an alloy thereof.

The closed cycle Brayton power system with direct heat transfer invention as disclosed in copending application, Navy Case No. 71843, has the problem that some of the liquid metal fuel vapor will be carried from the reactor/fuel exchanger into the working fluid stream. The volume fraction of metal vapor is relatively low; however, during a long run of the power cycle the metal accumulation can damage the regenerator, cooler, turbine, or compressor. The volume fraction of the vapor present is equal to the ratio of the partial pressure of the liquid metal to the system operating pressure, i.e. for aluminum @ 2343°F, 1mm Hg/~800 psi = 1.6×10^{-6}, for lithium @ 2323°F, 400 mm Hg/~800 psi = 6.5×10^{-4}.

SUMMARY OF THE INVENTION

Accordingly, it is a general purpose and object of the present invention to provide an improved reactor/storage tank for use in a direct contact closed Brayton cycle power system. It is a further object to provide metal vapor control within the reactor/storage tank to remove contaminants, such as metal fuel vapors, from the working fluid stream. Another object is to provide longer life in the power system components that come in contact with the working fluid.

These and other objects are accomplished with the present invention by providing a system in which O_2 is fed into the reactor/storage tank's filter cavity. This causes the metal vapors in the circulating working fluid stream to react directly with the O_2 forming a low volume of solid oxide particles at the closed Brayton cycle operating temperatures and pressures. These solid oxide particles settle out of the working gas before it exits the filter cavity.

BRIEF DESCRIPTION OF THE DRAWING

A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a diagram of a closed Brayton direct contact reactor/storage tank with an O_2 afterburner in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 there is shown a reactor/storage tank **10** for transferring heat from a liquid metal fuel **12** to a working gas in a closed Brayton cycle power system. Although the terminology reactor/storage tank and direct contact reactor/storage tank are used to describe component **10**, names such as heater/reactor housing and direct contact heater could be used.

In the preferred embodiment, a direct contact, metal reactor/storage tank is partially filled with a liquid metal fuel **12**. Reactor/storage tank **10** has a working gas inlet **14** tube disposed in reactor/storage tank **10** below the surface **12a** of liquid metal fuel **12** for the injection of the working gas directly into liquid metal fuel **12**. Working gas inlet **14** is a tube extending into reactor/storage tank **10** with a plurality of apertures **14a** therein, disposed along the length thereof. Similarly, a working gas outlet tube **16** is disposed in reactor/storage tank **10** above surface **12a** of liquid metal fuel **12** for the ejection of the working gas from reactor/storage tank **10**. The flow of the working gas is designated generally by flow arrows **18**. Also disposed within reactor/storage tank **10** is an oxidant injector tube **20**. An oxidant is introduced through

injector tube **20** into liquid metal fuel **12** where it reacts with fuel **12** to produce heat. An afterburner oxygen injector tube **22** is disposed in a filter cavity **24** above the surface **12a** of liquid metal fuel **12** for supplying an oxidant to filter cavity **24**. An electrically controllable oxidant injector control valve **26** communicates with an oxidant source 27 ~~(not shown)~~ for supplying an oxidant to afterburner oxidant injector **22** in filter cavity **24**.

The oxidizing agent or oxidant in the preferred embodiment is oxygen, O_2. The reaction between oxygen and an aluminum-magnesium alloy liquid metal fuel provides the preferred means of generating heat within reactor/storage tank **10**. The working gas is normally argon or a mixture of helium and xenon. Helium, argon and xenon are inert gases and therefore do not react with a metal fuel. Other possible choices for metal fuels include alkali metals, such as lithium, sodium or potassium.

Disposed within the reactor/storage tank **10** between liquid metal fuel **12** and working gas outlet tube **16** is a screen assembly **28** for preventing liquid metal fuel **12** from splattering into working gas outlet tube **16**. A filter **30**, which further prevents contaminants within the working gas from entering working gas outlet tube **16**, is disposed between screen assembly **28** and working gas outlet tube **16**. Typically, filter **30** is a ceramic fiber insulation filter.

In operation, after the metal fuel is heated to the liquid state, the working gas is injected through working gas inlet **14** into reactor/storage tank **10**. The working gas then bubbles

through liquid metal fuel **12**. Representative working gas bubbles **32** are shown leaving aperture **14a** and expanding toward surface **12a** of liquid metal fuel **12**. Heat is transferred directly from liquid metal fuel **12** to the working gas. During this process metal vapors are formed.

When the oxidant, preferably O_2, is injected into filter cavity **24** the metal vapors react directly with the oxidant while still inside filter cavity **24**. The small volume of solid metal oxide formed precipitates from the working gas, and remains on filter **30**, thereby removing the metal vapors from the working fluid. A high temperature oxidant sensor **34**, such as is used in automotive emission controls, and a temperature sensor **36** are disposed within working gas outlet **16** for detecting the presence of an oxidant in the exit stream. Oxidant sensor **34** and temperature sensor **36** are electrically connected to a valve controller **38** by oxidant sensor connection **40** and temperature sensor connection **42**. Valve controller **38** is electrically connected to oxidant injector control valve **26** by valve control cable **44**. Valve controller **38** reduces and increases the afterburner oxidant flow in response to the readings from oxidant sensor **34** and temperature sensor **36** to give a constant but very low concentration of oxidant in the exit gas stream.

The combination of screen assembly **28**, filter **30** and the afterburner injector tube **22** effectively clean the working gas before it passes through outlet tube **16**.

In alternative embodiments, the liquid fuel can be one of the alkali metals such as lithium, sodium, or potassium, and the oxidant can be a chlorofluorocarbon, such as $C_2F_3Cl_3$ known in the art as Freon-13. Chlorofluorocarbon oxidants cannot be used with aluminum-magnesium fuel, however, because the products of the oxidation reaction are gaseous at the operating temperature.

There has therefore been described a reactor/storage tank **10** that is used in a closed Brayton cycle. The reactor/storage tank has an afterburner injector tube **22** in filter cavity **24** that functions as an afterburner in the path of the working fluid to eliminate metal vapor from the working fluid. In the absence of this afterburner, any metal vapor present in the circulating working fluid plates out and eventually freezes at a point in the cycle where either the partial or total pressure of the gas stream is reduced, or the gas is cooled below the melting point of the vapor. These conditions occur in the turbine, regenerator, and cooler of the direct contact Brayton power cycle. The metal deposits can reduce heat transfer in the regenerator, damage the turbine, or cause a pressure drop in any of the components.

It will be understood that various changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.